

Inaugural Lecture of Professor A.T. Motlhabane

Towards conceptual change and re-thinking cognitive conflict in science

Department of Science and Technology Education

University of South Africa

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Acting Vice Chancellor Professor Moche, the management of the College of Education, colleagues, my family and friends: Allow me to address you on the topic “Towards conceptual change and re-thinking cognitive conflict in science”. Professor Jean Kriek: thank you for agreeing to respond to my lecture.

Introduction

I started teaching mathematics and physical science 24 years ago, in a school by the name of Malefo High School. It was a challenge, since I was very young – some of the learners were my age – but I survived. I joined university life in 2002, 16 years ago. In the last 16 years, I worked with academics from the former Potchefstroom University, now North West University; we trained teachers in both mathematics and physical science. I was responsible for teaching physics to secondary school teachers in the Sediba Project of the university. We trained hundreds of teachers in mathematics and physical science. In addition to our teaching responsibilities, we moved around the country training science teachers how to do practical work. In a month, we would train at more than 30 schools. Teachers enjoyed what we did very much.

I then joined the University of Johannesburg where I ventured into a different territory, that is, academic development and support. After that I joined the NRF’s Innovation Fund and was always on the road, training both teachers and learners about innovation in science. The Innovation Fund was eventually merged with several DST entities to form the Technology Innovation Agency, where I worked for a time. Thereafter I joined Unisa as senior lecturer, then associate professor and currently as a full professor of Science Education.

I completed my PhD 13 years ago, under the superb supervision of Dr Miriam Lemmer. My engagement with science learners and teachers during this journey has taught me there is a challenge regarding concept formation and conceptual change in science, especially in physics.

Teachers and learners have misconceptions about a number of concepts in physics. I started conceptualising research and engaging a number of schoolteachers in practical activities in an effort to restructure the physics concepts of learners and teachers. I used practical work as a teaching methodology because I believe science can only be properly understood when practical experiments are done. I believed that the misconceptions could be rectified by doing experiments to test the truthfulness of science. I believed that the number of misconceptions I came across in the teaching of science were the result of the absence of practical work in schools.

In many schools that I visited, there are no laboratories; if the laboratory existed, it was used for a different purpose and not for science experiments. In the past few years a number of schools have been provided with equipment for physics and chemistry experiments: I remember it was first scientific teaching aids, then Somerset Education, then combo plates, and then Corrie's small-scale sets. In many schools this equipment is deteriorating; in some, it is still in sealed boxes in the principal's office. The study I published entitled "The voice of the voiceless: reflections of science practical work in rural disadvantaged schools" describes the unsatisfactory conditions for doing practical work in science subjects in secondary schools (Motlhabane, 2013). The main feature of most classroom transactions in rural schools is the transfer of factual information through "chalk-and-talk" and confirmation of taught concepts using routine guided experimental approaches.

In many schools the teachers cannot do experiments. For example, I observed a teacher trying to explain the operation of a ticker timer in physics. In his lesson, the teacher said: "Imagine you have a ticker timer and it makes dots on the tape". The teacher then drew a ticker timer and a tape with ticks on the board. Then the teacher copied out the results of a previously recorded experiment. Learners were subsequently expected to interpret the results and apply what they had learnt to problems or questions on the ticker timer.

I was part of the maths and science indaba that was commissioned throughout the North West Province, partly to discuss the challenges in the teaching of the two subjects, that is mathematics and physical science. In one of the sessions, Ntate Seliki Tlhabane said: "How can teachers teach mathematics and science knowing only 30% of the work they are supposed to know?" "How can a doctor operate on a patient knowing only 30% of the work he or she is supposed to know?" "How can an engineer fix the potholes in our roads knowing only 30% of the work he or she is supposed to know?" He was referring to learners who are allowed to pass matric by obtaining only 30%. They get these poor marks because they imagine experiments –

they do not do them. I still very much believe in the notion “What I hear I forget; what I see, I remember; and what I do, I understand”. I am saying we need to work towards knowing at least 70% of the work we are studying. Currently the 70% we do not know is the cause of misconceptions, alternative conceptions and incorrect science; pre-knowledge that is not in line with scientific principles must be restructured.

This lecture is born out of a large body of research examining ways in which conceptual change can be achieved. The lecture aims to position conceptual change within the framework of cognitive conflict. It is my contention that for conceptual change to take place, the student’s current conceptual understanding of science should be challenged. We should teach students to reason as follows: “Can this be correct? It can’t be correct, so let’s test it. Yes, now it makes sense.” Let us teach our students by creating a conflict between what they know and what we are about to teach. My former lecturers and teachers will tell you that I did not come into the classroom and just accept it when they told me that the square root of negative 1 is plus or minus 1 (+/-1). I asked them “Why? Is it possible?” I would even go to the extent of saying “You must be joking! Are you sure?” This is what teachers should try and do. Learners should leave the classroom more knowledgeable than confused.

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This lecture addresses conceptual change in science by rethinking the cognitive conflict between correct science and incorrect science/misconceptions/alternative conceptions.

Findings from many studies over the past three decades show that students do not enter science classrooms without any pre-instructional knowledge or beliefs about the phenomena and concepts to be taught. Rather, students already hold deeply rooted conceptions and ideas that are not in harmony with the views of science (Duit & Treagust, 2003). This pre-instructional knowledge is given different names, including “naïve ideas, alternative conceptions, misconceptions, child science” and “incorrect science”. In this lecture, I use these terms interchangeably. In most cases, I use the terms “misconception” and “incorrect science”, simply meaning that the student has “missed” the correct science concept. I can still refer to these conceptions as “alternative conceptions”, meaning alternative views or meanings that are not in line with scientific principles.

The students’ misconceptions are very difficult to change, because they are not merely mistakes or false beliefs; instead, students possess their own cognitive support groups and defence mechanisms (Strike & Posner, 1992). Based on this viewpoint, the lecture proposes

the conceptual change model as a method to be applied to our teaching and learning methodologies in order to change students' misconceptions.

The conceptual change model describes learning as the interaction that takes place between a student's experience and his or her current conceptions. Therefore, many studies on conceptual change have focused on establishing conditions that promote situations where the student's existing conceptions are made explicit, and then are directly challenged to create a state of conflict. As a result, many conceptual change models incorporate specifically designed strategies called cognitive conflict approaches (Chan, Burtis & Bereiter, 1997).

I would therefore like to begin by outlining research on various misconceptions in science so that I can contextualise the lecture.

I must say that children and adults hold misconceptions about science concepts. I say this because many of children's initial ideas about physics are compatible with the adult concepts, thus demanding a major reconceptualisation analogous to a paradigm shift in scientific theory (Carey & Gelman, 2014).

The research done on children's misconceptions in primary science by Pine, Messer and St. John (2010) identified 130 misconceptions which children bring to the science classroom. For example, some children think "stones grow" and "taller people are older than shorter people" or that a battery will always light a bulb. In the minds of children, electricity is related to the heart; some of them find it hard to understand that a fridge uses electricity. Children find it difficult to understand electricity because they cannot see it, and we as teachers make it worse by referring to electric current as a flow of charge. We are unable to explain the exact meaning of the flow of charge to the learners; hence they expect to see something flowing through the cables. In addition, the concept of electricity in physics remains difficult for learners for a number of reasons. Because we cannot explain to learners the meaning of the term "electricity", they think that "electricity is an object which is 'boxed' in some way" (Pine et al, 2001) in the main switch.

Dr Rufus Wesi, who is sitting in this hall, has identified a number of misconceptions about electricity. Many of these misconceptions originate in our homes. We as adults and parents say to our children: "please go to the shop and buy batteries." But some of these things are not batteries, but cells. A cell is a single unit and a battery is a group of cells connected to each other. We have a cellphone, not a battery phone. However, in most cases we do not say "My cellphone is dead or flat": we say "My phone's battery is dead, I need to charge it." Even

the word “dead” is not scientific. We send our children to go and buy electricity. Can we really buy electricity? In addition, the media say Eskom will increase the cost of electricity by 20%. It is the terminology we use in our homes that contributes to many of the misconceptions children have.

Children experience similar difficulties with the concept of forces in physics because the children cannot see the forces: they can only see their effects. Many misconceptions are evident in our science classrooms, partly because children have naïve theories about science. Teachers also have unresolved naïve theories about science.

One of my Master’s students, Mr CD Nxumalo, studied primary school science teachers’ understanding of and practices in aspects of the Nature of Science (NOS) and Scientific Inquiry (SI). The results of his study showed that primary schoolteachers’ understanding of NOS was either naïve or uninformed.

In the life sciences, research by Treagust and Haslam (1987) shows that secondary school students cannot comprehend the nature and function of respiration and have little understanding of the relationship between photosynthesis and respiration in plants.

A study by Abrahams, Homer, Sharpe and Zhou (2015) on the prevalence of and reasons for some previously researched scientific misconceptions amongst English and Chinese undergraduate students shows that while similar misconceptions existed amongst both English and Chinese undergraduates, their prevalence was significantly higher amongst the English students. This difference appears to arise from differences in the way in which specific areas of physics are taught in both countries. I happened to be in the United States in 2014, where I was hosted by Professor Lederman at the Illinois Institute of Technology, Chicago as a visiting researcher for three months. Professor Lederman, my mentor, had a project where Chinese teachers and learners were trained in mathematics and physical science during the summer holidays: I was part of the project as an observer. What amazed me was that the Chinese government made it a point to have translators present. Professor Lederman and his colleagues would teach the teachers and learners in English, and the translator would translate every single word into their mother tongue. They simply did not want to go back to China with misconceptions derived from American English.

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Chicago.jpg

Another of my Master's students, Daniel Zisanhi, completed a study on the challenges of using English as a medium of science instruction to ESL learners. His study indicated that learners are challenged in a number of ways when English is used to teach science, especially if English is not their home language. The challenge in South Africa with using our home languages to teach science is that they are not as fully developed as they are in China. If a language is not fully developed, students create their own replacement words for physics concepts.

LL Tshiredo, also one of my Master's students, completed a study on the impact of curriculum change on the teaching and learning of science. What immediately came to my mind was that in most cases the new curriculum will contain new terminology and new teaching approaches. So, during the time when the teachers are still trying to adjust to the new curriculum, the students will become confused and will develop more misconceptions in addition to those they already possess. I did General Science in Standards 4, 5, 6 and 7. Nowadays it is given the name Natural Science. In addition, the department tried to be smart and renamed physics as Energy and Change, Chemistry as Matter and Materials, Biology as Life and Living and Geography as Earth and Beyond. I must say, our education system is failing our students and teachers by unnecessarily changing things that do not warrant any change.

Research by Preece (1997) on pre-service and practising secondary school science teachers' language and understanding of force and motion shows that many teachers, particularly biology and chemistry specialists, have misconceptions about forces. I must say that the misconceptions relating to some of the concepts have their roots in African languages. For instance, students use the word *matla* to refer to force, energy and power, and this has implications for their understanding of the meaning of these three concepts in physics.

Hekkenberg, Lemmer and Dekkers (2015) explored 36 South African physical science teachers' understanding of basic concepts in electric and magnetic fields from the perspective of concept confusion. Concept confusion is said to occur when features of one concept are incorrectly attributed to a different concept, in the case of this study to magnetic and electric fields. The results show six categories of aspects of electric and magnetic fields causing teachers' inability to distinguish between the two fields, with a consequent confusion of concepts. These categories are: sources of currents; sources of electric fields; sources of magnetic fields; the effects of electric and magnetic fields on materials; electric and magnetic forces; and the direction of the electric and magnetic forces.

Smit and Finegold (2007) argue that the nature of physics as a scientific discipline is largely determined by the models of reality it utilises. It is therefore appropriate that teachers of physics have a sound knowledge of the origin and nature of these models, their functions and the role they play in the development of the discipline. Their study investigated how final-year prospective physical science teachers studying at South African universities perceived models in physics. The overall conclusion drawn in the study is that these students are far from prepared to incorporate models properly into their teaching.

Another study (Jacobs, 1989) compared students' *perceived* understanding of commonplace physics terminology with their *actual* understanding of it. First-year university physics students were presented with a list of sentences containing 25 selected words which are lay terms, but which have specific meanings in physics discourse. A first test required them to identify whether or not they thought they understood the meanings of the given words. Comparisons of scores showed that the average student tested had an inadequate grasp of the meaning of *more than 15* of those words that he or she had professed to understand. It is surmised that this high degree of ignorance about the meaning of terms could be a significant obstacle in physics instruction.

The study I published recently, entitled *Learners' alternative and misconceptions in physics: A phenomenographic study* (Motlhabane, 2016a, attempted to determine the alternative conceptions and misconceptions of learners about selected motion-related concepts in physics. The research adds another dimension to understanding alternative conceptions in kinematics by qualitatively determining how learners describe/define a distance of 0m, a displacement of 0m, a speed of 0m/s, a velocity of 0m/s and an acceleration of 0m/ss. Data was gathered by means of a free response test. Senior high school (Grade 12) learners were purposefully selected to complete the test. Data were analysed by qualitatively interrogating the descriptions and related graphs and pictures to uncover the ways in which learners described these concepts. The research revealed that some learners were not able to comprehend the meaning of a displacement of 0m, thus they experienced challenges in understanding concepts such as a speed of 0m/s, a velocity of 0m/s and an acceleration of 0m/ss. The data seems to suggest that learners fail to formalise and contextualise "0" as a concept in kinematics.

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The learners described the velocity of 0m/s as follows:

Descriptions of a velocity of 0m/s
No work is done
When an object remains stationary over a period of time
An object travels a certain distance with no velocity at a particular time. Meaning it is stationary
There is no movement the object has stopped
Not covering any displacement in a certain time, which simply means not moving
A stationary object usually have zero velocity because it doesn't move
Being unable to move at the required velocity just standing
When something moving with initial velocity
When an object undergoes constant displacement , or gradual increase in displacement
Zero velocity is the time and the distance travelled for the object to reach certain point up or down left or right and then to return again
Without a car accelerating
No movement , no work, it's just stationary
The amount at which a body is travelling with is zero, that means it is standing still

Adapted from Motlhabane (2016a)

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The learners described the speed of 0m/s as follows:

Descriptions of a speed of 0m/s
The is no movement the object is just stationary

When an object does not increase or decrease its speed. It remains stationary
An object is stationary but tend to travel with zero speed
It is the same as a stationary object there is no movement
Covering no distance per time or in a certain time, not doing anything at all
When an object has 0 speed that means this object does not move it is stationary
The is no speed taken not moving anywhere
When something from the starting point but moving zero speed or not going anywhere
Is when the object has not undergone motion /distance over a particular time. When the object is at rest
Zero speed explains the distance and the time taken for one to complete or travel on a certain journey. This means that at zero speed it is not moving
A speed that is not increasing
There is no distance, there is no movement
The rate at which a body moves with is 0
A speed without moving

Adapted from Motlhabane (2016a)

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The learners described the acceleration of 0m/ss as follows:

Description of an acceleration of 0m/ss
When an object move at a constant velocity
No increase in speed just moves constantly
An object travels a certain distance with no acceleration , it does not increase its speed but at that point there is no speed
There is no increase in the velocity of the car it means it is constant velocity
No motion , or simply something that is not doing anything or moving
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Increasing
Something move from top to bottom, sliding to the ground
Is when the velocity of an object is constant , or the object experiences no velocity at a given time
Zero acceleration explains that object did not up or move up
If an object is not moving
No force exerted
There is no increase the speed at which a body is travelling
No force being made

Adapted from Motlhabane (2016a)

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The learners described the distance of 0m as follows:

	Descriptions of a distance of 0m
A	The zero distance means there is no distance covered
B	When an object is stationary or does not move over a period of time. (the total distance from point A to B)
C	When an object was stationary this means no distance has been travelled from point A to B
D	The is no movement taken
E	Being stationary or not moving at all
F	This object is not moving , its distance is 0, therefore it is stationary
G	There is no distance covered
H	There is no distance or if the distance is 0 that means is initial velocity
I	Is when the body or object has not undergone motion Basically when the body is at rest
J	There was no motion or movement done for a thing to move to either side of any direction.
K	It is a distance that is not taken

L	Nothing has been travelled, there is no movement of something, it is just stationary
M	No forward or backward movement has been taken
N	The is no distance being taken the object is constant

Adapted from Motlhabane (2016a)

The respondents in this research associated a distance of 0m with the object being stationary. The respondents used a variety of words to explain the scenario of a stationary object. The words included the phrases “no distance”, “no movement”, “no motion” and “stationary”. Though none of them included the phrase “zero path length”, their responses were interpreted to mean that the object did not cover any distance, hence was stationary.

Kinematics seems to pose a number of challenges for learners. Consistent with Roschelle (1998) quoted by Motlhabane (2016a), there is ample evidence that the students’ understanding of concepts such as velocity and acceleration is not complete. Learners experienced challenges in correctly defining the kinematics concepts. Generally, the majority of the respondents used the description of a distance equal to 0m to define a displacement of 0m. This finding is consistent with Lemmer (2013) quoted by Motlhabane (2016a), that learners confuse distance and displacement. Similarly, some learners think that displacement is the same as distance, the only difference being that displacement has a small value, that is, a shorter distance (Lemmer, 2013 quoted by Motlhabane, 2016a). Hence, when they were required to define a displacement of 0m and a distance of 0m, in their minds the two concepts were defined the same.

The research revealed that many learners’ descriptions included the words “nothing”/“no”, associating the “zero (0)” with “nothing”. This resulted in defining some of the concepts non-scientifically, hence the misconceptions displayed. One important reason for the misconceptions in definitions/descriptions of concepts was the learners’ association of zero (0) with their everyday mother-tongue speech. Since the concept “zero (0)” shares common properties with the concept “nothing” in their mother tongue, for these learners these properties were necessary and sufficient to define the concepts given in the test. The research also confirms that students hold misconceptions in kinematics. Furthermore, the research reveals that students fail to formalise and contextualise 0 as a concept in kinematics.

The results show that some of the respondents could not explain a speed of 0m/s, a velocity of 0m/s and an acceleration of 0m/ss. The implication is that, when a learner cannot

conceptualise the meaning of a displacement of 0m, he or she is likely to have difficulty understanding concepts such as a speed of 0m/s, a velocity of 0m/s and an acceleration of 0m/ss. In simple terms, learners may know that a relationship exists between certain kinematics concepts, but they are unable to accurately define concepts in terms of these relationships.

Responding to the meaning of a velocity of 0m/s, some respondents indicated that it means “no work done”. This can be explained by the fact that learners see the motion of an object as caused by an internally stored impetus (McCloskey quoted by Motlhabane, 2016a), for example force or energy. Work done is actually the energy transferred when a force moves an object over a distance; however learners used the same impetus theory – that because there is no work done (no energy transferred) then the object cannot move, meaning a velocity of 0m/s (Motlhabane, 2016a).

One of the reasons that can be attributed to the incorrect descriptions of these concepts is the fact that learners interpreted these concepts in the context of their mother tongue, Setswana. In Setswana, “0” means “nothing”. Added to that, the terms “acceleration”, “velocity” and “speed” are all represented by the same terminology in Setswana, thereby meaning the same thing as “moving faster” or “moving slower”. If the object is not moving faster or slower, then it is stopped or stationary. In other words, if the value of the acceleration, velocity, speed, distance or displacement is given a value of 0, then the term is described using terminology such as “not moving” or “stationary”. That is why most of the learners used the terms “stationary” or “not moving”. Similarly, the issue of language is consistent with findings by Lemmer (quoted by Motlhabane, 2016a), who also found that language and culture contribute to the alternative conceptions learners have of kinematic concepts.

To date the literature has shown that there are misconceptions in kinematics, but this research indicates misconceptions associated with the concept of “0” (zero) numerically attached to the concepts of distance, displacement, speed, velocity and acceleration. While this research does not offer a conclusive explanation of the alternative conceptions and misconceptions that learners have, it does offer new knowledge in the sphere of misconceptions in kinematics.

Studies of science misconceptions clearly indicate that much is required of us to transform our teaching methodologies to effectively bring about conceptual change.

One may say it is good to have misconceptions because we can use these misconceptions as a starting point for a classroom discussion or investigation. This is because according to Pine et

al (2000), a misconception can cause children to think and give reasons, leading to deeper discussions and investigations. Therefore, having a misconception may ensure that the student becomes cognitively active during an investigation. Although it is possible that students can investigate and recognise that their ideas about science concepts are wrong, it is also sometimes possible that students can still think that their conceptions about science are correct even if they are wrong. It takes a long time for students to be completely convinced that their ideas are wrong; therefore, conceptual change may take a long time. Students may continue with these misconceptions from one grade to the next. In most classrooms, teachers are not aware of students' misconceptions and therefore they are not in a position to correctly diagnose and correct them.

In the quest to find out what is happening when teachers teach, I observed six lessons where Ohm's law was being taught. I analysed the lessons to find out the level and quality of classroom talk. The research investigated how teachers teach towards conceptual change by analysing talk moves executed by both the teacher and learners. The results were as follows:

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Table 1 Talk moves in each category

Dimensions of Accountability talk	Lessons	L 1	L 2	L 3	L 4	L 5	L 6	Total	Mean	Standard Deviation
	Categories Talk moves									
Accountability to Learning Community (ALC)	Teacher's linking (T:L)				-		-			-
	Student's linking (S:L)				-		-	-		-

Accountability to Accurate Knowledge (AAK)	Asking for knowledge	11	19	6	25	10	8	79	13.17	7.305
	Providing with knowledge	10	17	12	23	9	7	78	13.0	5.97
Accountability to Rigorous Thinking (ART)	Asking for rigorous thinking	-	1	-	9	3	-	13	2.17	3.54
	Providing with rigorous thinking	-	2	-	2	3	-	7	1.17	1.33

Adapted from Motlhabane (2016b)

The results show that there were no talk moves related to linking ideas, either between the students themselves or between the teacher and the students. However, a significant number of talk moves related to asking for knowledge and providing knowledge was noted. The talk moves asking for rigorous thinking and providing rigorous thinking were lower in number.

An example of what transpired in one of the lessons is as follows:

Teacher: What is this? (Referring to a voltmeter)

Student: It is a voltmeter.

Teacher: What does it measure?

Student: It measures the potential difference between two points.

Teacher: What is potential difference?

Student: The work done in moving a positive charge from one point to another.

Teacher: What is the unit for potential difference?

Student: Volts.

Teacher: What is this? (Referring to an ammeter)

Student: It is an ammeter.

In the above example, the teacher asked for knowledge about the voltmeter and the students provided it by answering the teacher's questions. Most of the questions asked "What?" However, students provided specific and accurate knowledge as evidence to back up their contributions and there was a "commitment to getting the facts right" in the lesson discussion. During the lesson teachers did not press for accurate knowledge by asking students to support their contributions, hence the quality of classroom talk was compromised. Talk moves like "How?" "Give some examples" and "What do you mean?" did not feature in the lessons. To enhance the quality of talk, more talk could have been initiated by probing for more from the students.

The lessons were projected in the classroom and all the teachers viewed the lessons. The aim was to critique each lesson and learn from each other. Teachers valued the idea of seeing other teachers teaching and indicated that they had learned a lot from the experience. A lively debate and discussion was created.

Conceptual change

Science teachers should constantly find teaching methodologies that can lead to conceptual change in science learning. The term "conceptual change" (Duit & Treagust, 2003) has various meanings in the literature; the term "change" has often been misunderstood as being the exchange of pre-instructional conceptions for the science concepts. I agree with Duit (1999) that for conceptual change to occur, the pre-instructional conceptual structures of the learners have to be fundamentally restructured in order to allow understanding of the intended knowledge, that is, the acquisition of science concepts.

The lessons above confirm that bringing successful teaching approaches for stimulating conceptual change to normal classrooms is a major challenge, not only for teachers but also for researchers (Lee & Byun, 2011). Research (Duit & Treagust, 2003) on students' and teachers' conceptions and their roles in teaching and learning science has become one of the most important domains of science education research during the past three decades. Starting in the 1970s with the investigation of students' pre-instructional conceptions of various science-content domains such as the electric circuit, force, energy, combustion, and evolution, the analysis of students' understanding across most science domains has been comprehensively documented by Duit (2002).

Learning science concepts, including complex concepts such as Newton's laws of physics, involves restructuring students' previously held misconceptions (Loyens, Jones, Mikkers & Van Gog, 2015). This restructuring, or conceptual change process, typically requires the learner to thoughtfully and critically weigh the contrasting information between the scientific explanation and their prior misconception. Instructional interventions that incorporate processes such as a critical analysis of arguments increase the likelihood of conceptual change occurring (Dole & Sinatra, 1998 quoted by Loyens et al (2015)). The use of a problem-solving task provides opportunities for students to modify or replace their prior knowledge with the scientific viewpoint in order to successfully answer the questions posed.

The research on the acquisition of science concepts has rich implications for the teaching of science and can lead to the development of useful principles for the design of learning environments (Vosniadou, Loannides, Dimitrakopoulou & Papademetriou, 2001). Contrary to the lessons I observed, in the research done on designing learning environments to promote conceptual change in science (Vosniadou et al, 2001), the students were encouraged to take active control of their learning, express and support their ideas, make predictions and hypotheses and test them by conducting experiments. They worked in small groups and presented their work to the class for debate. Metaconceptual awareness was promoted by encouraging students to make their ideas overt, to test them and compare them with those of other students and to give scientific explanations. The research shows that classroom debate can help to clarify the variables contributing to the observed conceptual change.

Conceptual change is likely to occur (Strike & Posner, 1992) under the following conditions:

Firstly, there must be dissatisfaction with existing conceptions.

Secondly, a new conception must be intelligible.

Thirdly, a new conception must appear initially plausible.

Lastly, a new concept should suggest the possibility of a fruitful research.

This lecture emphasises that the role of the teacher (Pine et al, 2001) is to organise the child's naïve ideas into coherent concepts which are both accurate and explicit. However, whether this involves discarding and replacing the initial knowledge, or reorganising and developing it, is a question that gives rise to two opposing views about how conceptual development in science occurs. The argument in this lecture is that the process of conceptual change should focus on a

conflict between two sets of knowledge, where the child's incorrect child science/misconception/alternative conceptions are restructured into a more correct concept.

This restructuring position (Pine et al, 2001) is also adopted by Spelke (1991), who argues that initial knowledge is elaborated with experience, but that fundamental principles are neither abandoned nor replaced. If new knowledge is built from preconceived knowledge, then the all the naïve ideas that children bring with them to the classroom should play an important role in the process of conceptual change.

Acting Vice Chancellor, I argue that one means of improving the application of misconceptions research is by creating a cognitive conflict in the science classroom.

Cognitive conflict

A study done in middle schools in Korea (Kang, Scharmann & Noh, 2004) shows that there was a significant correlation between cognitive conflict and conceptual change. This study looked at the role of cognitive conflict in science concept learning. Tests regarding logical thinking ability, field dependence/independence, and meaningful learning approach were administered. A preconception test and a test of responses to a discrepant event were also administered. Computer-assisted instruction was then provided to students as a conceptual change intervention. A conception test was administered as a post-test. In analysing students' responses to the discrepant event, seven types of response were identified: rejection, re-interpretation, exclusion, uncertainty, peripheral belief change, belief decrease, and belief change.

Bao, Kim, Raplinger, Han & Koenig (2014) investigated affective factors in STEM learning and scientific enquiry and assessed cognitive conflict and anxiety. They concluded that cognitive conflict can also contribute to student anxiety during learning, which can have both positive and negative impacts on students' motivation and learning achievement. A study by Mogonea and Popescu (2015) analysed the effects of educational training in the use of sociocognitive conflict to optimise future teachers' learning. The main research methods used in the experimental research conducted were an enquiry-based questionnaire, test knowledge, pedagogical experiment, and psychoanalysis of students' work. The formative experiment involved the use of models and strategies for encouraging sociocognitive conflict in student learning. The results demonstrated the effectiveness of constructivist instructional models that promote sociocognitive conflict and cooperation-based activity.

Baddock and Bucat (2008) investigated the effectiveness of a classroom chemistry demonstration using the cognitive conflict strategy. Students were shown the colour of methyl violet indicator in some hydrochloric acid solutions and then in acetic acid solution. The intention was to create a cognitive conflict, resolution of which would lead to an understanding of the concept of “weak acid”. Student learning emanating from the demonstration was evaluated by written answers to the following: “Describe the demonstration”, “What was the aim of the demonstration?”, “Explain the observations”, and “What do you think you have learned?” Learning outcomes were disappointing, not because of failure to resolve the intended conflict, but because of failure to attend to the key features of the demonstration and recognise a conflict. Some interesting cases of unintended, and undesirable, learning occurred. Consistent with Limon (2001), conceptual change via the instructional strategy of cognitive conflict is not a function only of the students. The success of demonstrations like these (Baddock & Bucat, 2008) is highly dependent on how the teacher interacts with both the phenomenon demonstrated and the students. Cognitive conflict (Limon, 2001) seems to be a starting point in the process of conceptual change. To start the process of change, this conflict has to be meaningful for the individual. A lack of meaningfulness may explain some of the difficulties encountered with the cognitive conflict strategy when it has been implemented in the classroom. To induce a meaningful cognitive conflict, students should be motivated and interested in the topic, activate their prior knowledge, and have certain epistemological beliefs and adequate reasoning abilities to apply.

Hewson and Hewson (1984) argue that conceptual conflict has long been recognised as a factor that could facilitate student learning. Its potential use in instruction is particularly relevant in the light of the recent, well-documented finding that students’ existing conceptions frequently constitute a barrier to effective learning. The analysis (Hewson & Hewson, 1985) shows that the conceptual change model provides an explanation of conceptual conflict which is sufficiently detailed to allow it to be used in instruction design.

Research by Niaz (1995) shows that cognitive conflicts used in the teaching of experiments must be based on problem-solving strategies that students find relatively convincing. Moreover, after having generated a cognitive conflict, it is essential that the students be provided with an experience that could facilitate the resolution of the conflict; and that the teaching strategy developed uses an interactive constructivist approach within an intact classroom.

A study I have done on concept mapping/mind mapping (Motlhabane, 2013) to try and engage teachers in the construction of concept maps involved teachers constructing maps of the concept of energy in groups. Thereafter, the maps were presented to the class by group leaders. Since every individual teacher had a different understanding of the concept of energy, their different cognitive structures led to a very thought-provoking and interesting discussion. That is what I mean by cognitive conflict: the conflict that arose because of the different maps presented sparked a lively debate in the classroom.

As an example, there was debate about the meaning of energy as the ability to do work. Some teacher suggestions were:

“the power or ability to facilitate or do work”

“the power that someone uses to bring change on an object”

“the power that enable something to perform”

“the energy is there”

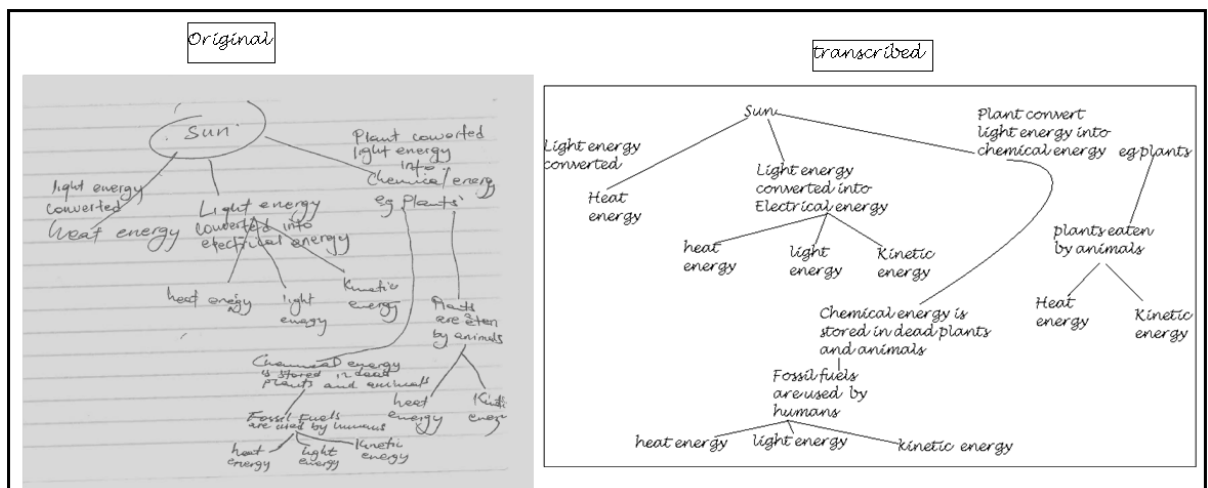
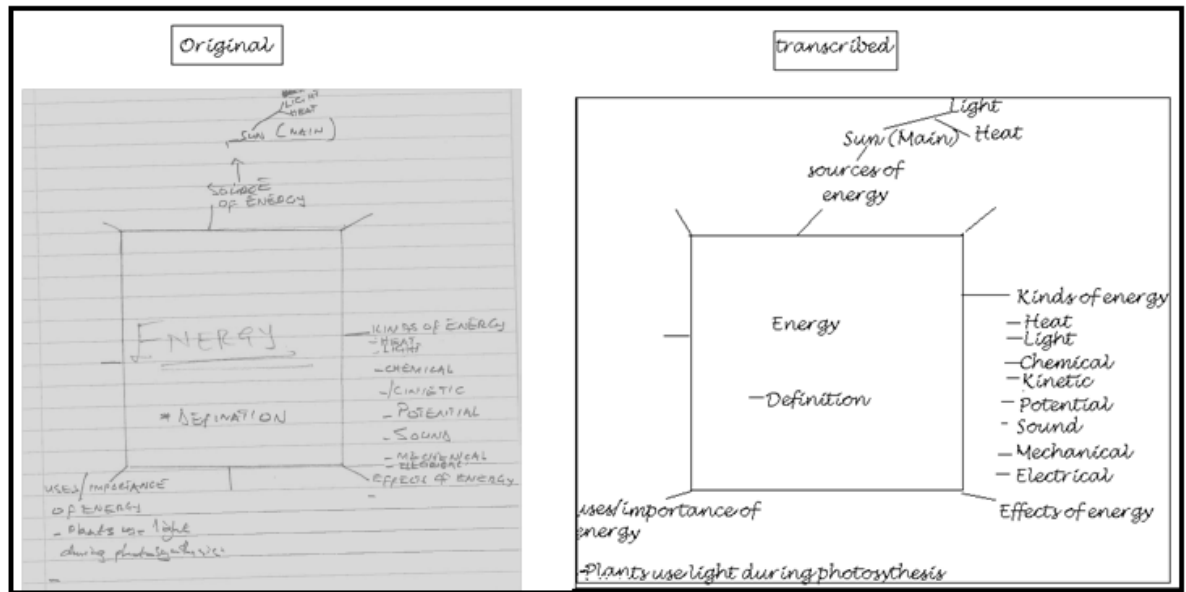
“transformation of energy”

During the debate I could see that teachers confused power and energy. However, this is not surprising, as indicated in this lecture; in some languages like Setswana, power, energy and force are translated by the same word, *matla*.

In the process of this lively debate, conceptual change happened when some of the teachers realised that their concept of energy was wrong.

Examples of concept maps drawn by teachers are given below.

Slide



Adapted from (Motlhabane 2013)

Conclusion

In order to reach a state of cognitive conflict, students need to determine whether the new knowledge presented is valid or not and whether new knowledge is congruent or not with their existing conceptions (Chinn & Brewer, 1993). In fact, for conceptual change to occur, students should be exposed to a physical experience that provides them with novel evidence to contradict their existing conceptions.

The constructivist view of learning pays special attention to students' prior knowledge. One of the core tenets of this view is the necessity of connecting students' prior knowledge with the new contents to be taught. I argue that through thoroughly constructed lessons

presenting cognitive conflict, the new knowledge to be acquired by students can be connected with their existing prior knowledge. This means creating a conflict between the students' misconceptions and correct science. The pioneer model of Posner, Strike, Hewson & Gertzog (1982) considered the phase of conflict, generated by dissatisfaction with the existing concepts, as a first step to achieving conceptual change. In this phase of dissatisfaction, students should realise they need to "re-organise", "restructure" or change their existing ideas or concepts to some extent. It seems that to change something, an individual needs to realise that this is necessary and be willing to do it.

Therefore, instructional strategies that can be used to restructure students' prior conceptions of scientific phenomena should be developed to promote conceptual change. As this lecture recommends, one of the conceptual change instructional strategies suggested is to induce cognitive conflict by presenting contradictory and conflicting knowledge in the science classroom.

Put simply, new learning occurs when provoked by a surprise, contradiction or obstacle. In this way cognitive conflict acts as a springboard for learners to want to find out more, an awakening, and as such it is a powerful method for moving learning on. It can also help learners to develop their thinking away from the concrete and factual. Lessons involving cognitive conflict are exciting for the learner and rewarding for the teacher (Sayce, 2009).

Cognitive conflict is well recognised as an important factor in conceptual change and is widely used in developing enquiry-based curricula. Therefore, teachers need to be informed of the impacts of introducing cognitive conflicts during teaching. To get this information, teachers need a practical instrument that can help them identify the existence and features of cognitive conflict introduced by the instruction, and the resulting anxiety.

This lecture argues that current classroom practice overlooks the conditions of creating an environment where learners' existing conceptions, beliefs and values can be challenged and restructured.

The environment where the conflict resolution process is created is critical, since ineffective resolution may leave the student with unintended or inappropriate interpretations, or in a state of confusion. The physics lessons observed provide an example of the recognition and resolution of conceptual conflict through class debate.

Creating a cognitive conflict approach involves identifying students' current state of knowledge and bringing about conflict so that they can replace the preconception with a

scientifically accepted conception (Posner et al, 1982). The concept of cognitive conflict has also had great influence on science education researchers, especially those who work in the area of concept learning. Some of these researchers regard cognitive conflict as a necessary condition for conceptual change in learning science concepts.

Planning for cognitive conflict

1. Present learners with already constructed concept maps. Learners can now debate the truthfulness and correctness of the concept maps until a consensus is reached. The maps will spark debate in the classroom, as they will contradict students' cognitive conceptions of the concept presented.

2. Use a misconception to spark a classroom debate, but do not tell the students that it is a misconception.

3. Predict key issues that can cause a conflict. For example, have teachers watch video-recorded lessons as described earlier. This will spark a discussion of the teaching methodologies used in the recorded lessons, which will help teachers restructure their own teaching methodologies.

I would like to conclude by saying that the resolution of the cognitive conflict between students' reasoning about a science concept, alternative conceptions, misconceptions, naïve ideas, incorrect science and their everyday experience can lead to a better understanding of concepts, and ultimately to conceptual change.

Below are illustrations of my engagement with teachers and learners towards conceptual change in science.



Project 3.jpg

Engaging critically with science learners



Project 4
teachers.jpg

Engaging teachers in a workshop. I am looking carefully at what the teachers submitted to me.



Project learners.jpg

One of the learners asking me: “Is it really possible?” after I caused a conflict in the classroom intended to lead to conceptual change.



Moses Kotane
Project 3.jpg

Professor Bobo Segoe, Mr Kolokoto (subject advisor for mathematics), learners from different schools and me after a well-organised Saturday class in Rakoko High School, Mabieskraal



Teachers
Workshops.jpg

Workshops with science teachers



Moses Kotane
Project.jpg

Professor Bobo Segoe, very tired after a long day in Mabieskraal



Presenting at a
conference.jpg

Presenting at an international conference



Project 5.jpg

Learners listening to me

In one of the projects led by Professor Bobo Segoe we travelled to the deep rural areas of Rustenburg, making sure that the Grade 9 learners get the best training.

Thank you, Dr Mohapi, for allocating funds to my project.

I would like to sincerely thank the following individuals:

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Thank you for teaching me that mathematics is an easy subject. However, I reached a stage where I decided to make mathematics a hobby rather than a career.

Mrs Helen Thomas

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Rakoko High School teachers

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Mrs Mabule

Ms Baby Motene

Mantsho Primary School

MmaModisakeng, may her soul rest in peace.

MmaSeeletso

MmaDiole

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Prof. Faan Nel, former Master's supervisor

Mr Dolo, former chemistry lecturer

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Prof. Letseka, former leader, o buile wa re retlogele go ja mamina mo diofising

Prof. McKay, Executive Dean of the College of Education

Prof. Sebate, Deputy Executive Dean of the College of Education

Family:

My children, Dichomi tsa papa, Tshepi, Tshego, and Tsholo

My wife, Mamistro Mmatshapo

My siblings, Kereng and Gontse

Akasia Parish Block C members present, ke a leboga



Mother.jpg

My mother, may her soul rest in peace.

My grandfather, may his soul rest in peace.

My in-laws, Ntate Kgosimang and MmaKgosimang

Mama Koko Ntlapi ke lebogela kgodiso ya gago

and Ntate, may his soul rest in peace.



mother 2.jpg

The Lord God

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